Management effectiveness of a biodiversity monitoring programme: Fledging success of White-tailed Tropicbirds *Phaethon lepturus* in the Seychelles.

April J. Burt1,2 \* Fernando Cagua1,3 Cheryl Sanchez 3,1, Licia Calabrese5, Janske van de Crommenacker5, James McClelland6 Nancy Bunbury1

*1Seychelles Islands Foundation, P.O. Box 853, Victoria, Mahé, Seychelles*

*2Zoology Department, University of Oxford, Oxford UK*

*3Centre for Integrative Ecology, School of Biological Sciences, University of Canterbury, Christchurch, New Zealand*

*3Nature Seychelles, Centre for Environment & Education, Roche Caiman, P.O. Box 1310, Mahé, Seychelles*

*4 Island Conservation Society,* *Pointe Larue, Mahé, Seychelles, PO Box 775*

*5 Green Islands Foundation*

*6Cousine Island Company Limited, P.O. Box 977, Victoria, Mahé, Seychelles*

**Abstract**

The successful design and implementation of monitoring programmes is an important tool in the effective management of biodiversity. To test the effectiveness of a regionally important monitoring programme we combined monitoring efforts from five of the regions most vital nesting sites for white-tailed tropicbirds *Phaethon lepturus*.We present data on fledging success at each of the sites and show that at Aldabra atoll on average 15.2% of nests were successful compared with 33% on Cousin Island, 40.2% on Aride Island, 51.6% on Cousine Island and 55% on Denis Island. In addition, at Aldabra there was a significant negative temporal trend in fledging success observed. The Aride Island population showed a continuous negative trend in nest density since 2011, whereas the Cousine island population density increases. However, disparity in methods, duration and longevity of programmes prevented direct statistical comparisons between sites, though the regional outlook was beneficial for determining potential drivers of change at site level. Whilst great efforts to monitor biodiversity are being made across the Seychelles the data is not being fully utilised, at least not frequently enough, or at a high enough level to fulfil the true value of such data within a conservation management context. Recommendations are therefore made to improve the effectiveness of these conservation efforts by defining regional management values, developing a common protocol and collaborating between organisations and managers to ensure data collection leads to informing management of biodiversity.

Keywords: Seychelles, Tropicbirds, Management, Ecology, Feeding, Breeding

\*Corresponding author.   
Email address: april.burt@queens.ox.ac.uk (A. J. Burt).

**1. Introduction**

The effective management of biodiversity is paramount to achieving the Sustainable Development Goals set out by the United Nations in 2015. Management effectiveness is often measured by assessing the condition and trend of specific values (Leverington et al. 2010) through biodiversity monitoring programmes. Ongoing monitoring and management is therefore integral to conservation of biodiversity but is an often neglected or poorly executed part of the conservation process (Regan et al. 2008). Barriers to success include; (i) poorly articulated or vague objectives contributing to design and implementation problems; (ii) organisational boundaries; (iii) lack of institutional capacity resulting in data piling up without rigorous analysis; (iv) lack of the appropriate standards to guide monitoring activities and make data available from these programmes (Lindenmayer et al. 2012; Reynolds et al. 2016). Successful monitoring requires strong collaboration among managers, ecologists and data scientists, especially in regions where there are multiple organisations managing the biological diversity of the region, such as small island developing states.

The Seychelles archipelago is an important case study with respect to the effective management of biodiversity within the small island developing states. With 115 islands stretching across an exclusive economic zone of 3.2 million km2 the Seychelles islands are a challenging location for articulated monitoring at the same time they are a hotspot for biodiversity. The Republic of Seychelles was recently named one of five small island nations declared world leaders in conserving threatened species (Rodrigues et al. 2014) and there is widespread emphasis throughout the Seychelles in collecting valuable data for use in conservation management. Monitoring programmes are conducted not just by NGOs and public trust conservation organisations but also on private islands where there is now a precedent for having a conservation staff team. These efforts are not to be under-estimated and should be encouraged, however it is important to ensure that the effort put in is justified by the value of the data. A clear understanding of how the information derived from the monitoring may help to conserve the species is required.

Here, for the first time, we compile and report data from long-term monitoring of an important seabird species *Phaethon lepturus* (White-tailed Tropicbird) at the national level. Our primary objectives are to: (1) identify and compare trends in fledging success across different islands; (2) assess whether the monitoring programmes in place are adequate to assess the trends in nesting population density and fledging success and infer factors influencing this; and (3) outline ways to ensure that monitoring data is both sufficient and able to feed back into conservation management actions. We aim to streamline the monitoring programme for *P. lepturus* across the Seychelles, to define clear research aims, to ensure monitoring efforts fulfil research aims, and to allow direct comparability between sites. We also provide the framework to apply the data acquired to conservation management strategies nationally and further afield.

Fledging success in seabirds (measured as proportion of nesting attempts that fledge offspring) can be used as a measure of health of the species as well as providing an indication of overall state of the surrounding ecosystem (Parsons et al. 2008; Piatt et al. 2007). For this reason, monitoring the fledging success of seabird species has been adopted worldwide at seabird breeding sites. Fledging success at sites can be influenced by climate (Ancona et al., 2011), food availability (Hamer et al., 1993; Dearborn et al., 2001), invasive alien species (Russel and Le Corre, 2009) and intra/interspecific competition (Coulson, 2001; Dobson and Madeiros, 2010).

The Seychelles support the greatest abundance of tropical seabirds in the Indian Ocean with a total seabird population estimated at ca 3.3 million pairs across 16 species (le Corre et al. 2012; Sur et al. 2013; Burger & Betts, 2001; Diamond 1971; Rocomora et al. 2003)*. P.lepturus* range across much of the tropical oceans, including the southern Indian Ocean (del Hoyo et al. 1992; Safford and Hawkins, 2013).It is estimated that 56% of the *P. lepturus* population in the Western Indian Ocean (WIO) breed in Seychelles (le Corre et al. 2012), other WIO populations include Europa Island, Mauritius, Reunion, Rodriguez, Comores and Madagascar (Le Corre et al, 2008).

Seabird populations in the Seychelles have been threatened by habitat loss, alien predators, and over-utilisation as a food source; with expanding fishery activity and climate change also posing threats (Bristol, 2007). Although *P. lepturus* is listed as ‘Least Concern’ on the IUCN red list, the species is suspected to be in decline owing to predation by invasive species at nesting sites (IUCN Red List). However, the regional conservation status is unknown. Most islands in Seychelles that support breeding colonies of *P. lepturus* are small and invasive predator free or are very remote islands.

**2. Material and methods**

We analysed data available from five islands in the Seychelles: Aldabra Atoll, Aride Island, Cousin Island, Cousine Island, and Denis Island (Figure 1). These sites cover the main breeding sites in Seychelles for *P.lepturus* (Aldabra, Cousin, Cousine & Aride) as well as Denis island, of which little is known about the *P.lepturus* population. Other islands do have *P.lepturus* breeding populations though most are un-monitored. All monitoring programmes were developed separately and despite being based on the methods in the “Seabird monitoring handbook for Seychelles” (ref, date), this book merely describes how to obtain breeding success data, not specifically how to set up a long-term monitoring programme. The sites vary in size, geomorphology, elevation, protected status, management types, predator threats and *P.lepturus* population size (Table 1). The studies varied in area covered, monitoring duration, frequency, methods and monitoring area habitat type (Table 2).

For all five islands, nesting *P. lepturus* were defined as an adult with an egg or a chick on a nest, though new nesting attempts were only included in the dataset when the attempt was at the egg incubation stage to avoid a biased result caused by selecting nesting attempts that had already successfully reached chick stage. Nests were checked (and new nests searched for) between every 2–3 days and every two weeks, depending on the island (see Table 2). To determine nest outcome, the stage at which the nest was last observed active was recorded. If a nest was observed to have been occupied by an egg or a young (partially feathered) chick and it was subsequently observed empty or with signs of predation/death on the succeeding visit, it was assumed that the nest had failed. If a nest was observed to be occupied by a fully feathered chick and then found empty in the subsequent visit without signs of predation/death, it was assumed that fledging had occurred and therefore that the nest was successful (hereafter fledging success). For those sites that monitored all nests within a specific area (Aride, Aldabra, Cousine) the number of nests is hereafter referred to as nesting density and is used as a proxy for breeding population size.

Aldabra Atoll

Aldabra Atoll is a raised coral atoll, approximately 1150km southwest of the main Seychelles island of Mahé (Figure 1), and consists of four main islands totalling 155 km2 area around a central 195.9 km2 lagoon. *P. lepturus* nest predominantly on islets within the lagoon. The habitat of the islets (area between 41 and 570 m² (mean 249 m²) consists of pitted limestone crevices and salt tolerant vegetation with varying degrees of coverage. Tropicbird breeding was monitored consistently on 13 lagoon islets and an outcrop of Picard Island. During each nesting survey, the entire monitoring area was searched to ensure all new nests were recorded. The last assessment of *P. lepturus* fledging success on Aldabra was in 1980 (Prys-Jones et al.).

Aride Island

Aride is the northernmost granitic island of the Seychelles Archipelago and is situated 15 km away from Cousin Island and 50 km from the main island of Mahé (Figure 1). Aride’s 74 ha consist of 5 ha of flat plateau and 69 ha of mountainous terrain. The island has been restored from a degraded coconut plantation. A colony of *P. lepturus* nests across the island but monitoring is consistently conducted on the plateau along coastal and inland areas of forest. During each nesting survey, the entire monitoring area was searched to ensure all new nests were recorded. The last assessment of fledging success was in 2005 (Ramos et al).

Cousin Island

Cousin is 2 km from Cousine Island and 35km from the main island of Mahé (Figure 1). Cousin’s 27 ha consist of 21.6 ha of flat plateau and 5.4 ha of mountainous terrain. The island has been restored from a degraded coconut plantation. A colony of *P. lepturus* nests throughout this habitat but are predominantly monitored on the plateau both along the coast and inland. Tropicbird monitoring efforts have been consistent since 2005 until present (with two years of missing data: 2008 and 2012). The survey effort is defined by a set number of nests rather than a specific area. Approximately 100 nests at incubation stage are selected once per year in February (although additional surveys were conducted in July on several years) and each nesting attempt is followed until the outcome (and stage) can be determined, providing a snapshot of percentage fledging success. The last assessment of fledging success was 1987 (Phillips).

Cousine Island

Cousine Island, 2 km west of Cousin and 32 km NE of the main island of Mahé (Figure 1). The island is close in proximity, size and habitat to Cousin Island and likewise has been restored from a degraded coconut plantation. A colony of *P. lepturus* breeds across the island but monitoring has concentrated throughout the accessible plateau on the eastern side. All known nest sites in this area (ca. 90 sites) are continuously monitored throughout the year for new nests and to record nest outcomes. The last assessment of fledging success was conducted in 2003 to 2005 (Malan et al, 2010).

Denis Island

Denis Island is ca. 43 km north of Aride Island and 80 km north-east of the main island of Mahé (Figure 1). Denis holds a small population of *P. lepturus* which nest across the island. Nest monitoring is island-wide and follows similar methods to Aride, Cousine and Aldabra whereby a specific area (Table 2) of the island has been monitored consistently from Nov 2015 to Sept 2016. All new nests in the area monitored and nest outcome recorded. This is the first assessment of *P. lepturus* fledging success for Denis Island.

*Data analysis*

Due to the differences in data collection methods, duration and longevity of each monitoring programme we were unable to compare between sites. We therefore present overall breeding success, and temporal trends in breeding success and nesting density wherever possible.

We were able to analise temporal trends for Aldabra, Aride, and Cousine. To do that, we employed a set of Generalised Additive Models (GAM) in each location with nest density or breeding success as a response variable. Nest density was defined as the number of new nests recorded within the monitoring area per month while breeding success as a binomial variable (nest fledged = 1; nest failed = 0). We employed a normal and binomial error structure for the density and success models respectively. We included two independent variables as smooth terms, ‘date’ and ‘month’ in order to assess long term trends while accounting for the possible seasonality in the response variables. Survey effort was constant over the year in all these tree locations, and as we are not performing comparisons across sites it was not necessary to account for differences among the areas surveyed.

Data for Cousin and Denis Islands were insufficient to perform this analysis and therefore only annual average breeding success was included for these sites. Cousin data was collected using a selection of nests chosen at one point in the year and this selection was followed until all outcomes were accounted for, no additional nests were added. Also, the number of nests monitored was not constrained by survey area, simply a sample of nests were chosen. The Denis Island monitoring programme was in-place for just under one full year. Whilst we acknowledge the effect these differences have on the data obtained we believe for the purpose of gaining a general indication of breeding success at each site, the data obtained from these sites was sufficient. Highlighting the differences in methods is also a key aim of this study and we therefore take this up in the discussion.

**3. Results**

Table 3 shows a summary of all results. Fledging success (% of successful nests) was highest at Denis Island followed by Cousine Island and lowest at Aldabra Atoll during the periods in which these sites were monitored. The proportion of nest failures at egg stage did not vary greatly between sites.

No variation in nesting density (the number of new nesting attempts recorded per year) was observed at Aldabra, a decline in nesting density was observed over time at Aride (df=1.6, x2=35.2, p=<0.05; Fig 2A; Table 4) and an increase in nesting density was observed on Cousine (df=1.9, x2=29.2, p=<0.05; Fig 2A; Table 4).

Fledging success remained constant over the years in which monitoring was carried out on all islands except Aldabra, where a decreasing trend was observed over time (df=1, x2=7.61, p=<0.05; Fig 2B; Table 4).

On Aride nesting density showed a seasonal pattern with a peak during September and October, a secondary peak between April and June and a low in December and January (df= 3.8, x2=49.1, p=<0.05; Fig 3; Table 4). Seasonality in nest density is present though weaker on Cousine (df= 3.1, x2=12.7, p=<0.05; Fig 3; Table 4) and virtually nonexistent on Aldabra.

**4. Discussion**

***Fledging success***

To identify trends in nesting population density and fledging success and to test the value of the data within a seabird hotspot region we combined monitoring efforts from the five most vital nesting sites for white-tailed tropicbirds in the Seychelles. This first national study of *P.lepturus* fledging success showed fledging success varied greatly between the study sites. The lowest was recorded at Aldabra Atoll, the most isolated site and the only site with invasive rats present. Aldabra has one of the lowest records of fledging success for *P.lepturus* throughout their range, though similar to that found at Fernando de Noronha archipelago, in Brazil – the largest colony of *P. lepturus* in the South Atlantic. Here 14.3% of nesting attempts were successful and predation at egg stage accounted for 50% of the attempts with the low success being attributed mainly to predation by crabs and nest exposure (Leal et al. 2016). The lowest fledging success for *P.Lepturus* has been recorded at Europa Island at 6.9% for non-rat controlled habitats (Ringler, et al., 2015). Aldabra therefore conforms to results obtained from other studies where invasive predators are present and supports the claim that in the case of Tropicbirds, predation by invasive species (mainly rats – Russel & La Corre 2009; Sarmento et al., 2014) and native species (mainly large crabs - Phillips, 1987; Schaffner, 1991) is the main cause of mortality during breeding. It is therefore reasonable to conclude that for the sites with no long-term negative trend detected, the differences observed in fledging success are mostly due to the level and combination of predators at site level. Aldabra has a different combination of potential predators to the other sites (Coconut crabs, rats, grey heron, drongo) that may account for the lower overall fledging success.

This does not however account for why fledgling success has been decreasing on Aldabra over this study period. This decline is reinforced by the earlier studies of *P.lepturus* fledging success at Aldabra, which found fledgling success to be much higher 30–35 years ago (47.5% recorded by Diamond in 1975; and 46% recorded by Prys-Jones in 1980). Of all the known and potential predators listed for Aldabra, all except rats are also monitored and none have shown increasing trends (SIF unpublished data). An increase in drought periods reported for Aldabra (Haverkamp et al., 2017) is unlikely to have directly impacted *P.Lepturus* fledging success due to their choice of limestone crevices as sheltered nest sites rather than vegetation cover. Sheltered nests have more stable ambient temperatures (Hart, Downs, and Brown 2016b) and site selection offsets difficulties imposed by the weather. There also appears to have been no changes in nesting seasonality with none apparent in earlier studies (Diamond, 1975; Prys-Jones, 1980) as well as this one. In-fact the differences in seasonality observed between Aldabra, Aride and Cousine may well be as a consequence of the level in which *P.Lepturus* are nesting in rock crevices or in vegetation at each site, though this is not investigated further in this study. In conclusion for Aldabra; this monitoring programme was sufficient to detect a trend and to some extent rule out several factors that may have caused such a trend but overall it was not possible to distinguish the drivers of a decline in fledging success. Further investigation into both internal factors such as nest site competition and predation as well as external factors such as food availability are required.

The remainder of our sites have fledging success averages that are more aligned with that found elsewhere; 30% in Ascension Island (Stonehouse 1962), 21% Cayo Luis Peia, Puerto Rico (Schaffner 1991). The highest fledging success recorded globally is across eight islands in Bermuda where success averaged 70.6% and all sites are managed as nature reserves with active exclusion of mammal predators including rats, cats and dogs (Madeiros, 2008). The lack of fledging success trends detected at the other sites within this study is reinforced by comparisons with previous reports; on Cousine 51.6% nesting success was recorded compared to 25% by Malan (2010); Cousin averaged 33% in this study compared to the 36% recorded by Phillips in 1987, Aride averaging 40.2% compared to the 21-37% recorded by Ramos et al. in 2005.

Our results also showed that nesting density remained stable at Aldabra, showed a slight upwards trend at Cousine but we observed a continuous negative trend on Aride. This decline on Aride was previously reported; Bowler et al. (2002) showed that the nesting population of *P. lepturus* suffered an apparent decline of 60% between 1989 and 1998, and our results and unpublished census data also support the continuation of this decline. There are two key factors that suggest population decline on Aride is caused by adult survival at the site; firstly that Aride continues to maintain relatively high and stable fledging success along with Cousine and Cousin and secondly, that neighbouring island Cousin maintains a stable population trend (1987 to 2014, unpublished census data) and Cousine island shows an increasing population trend (this study and 2003 to 2017 unpublished census data). For these islands that are within close geographical proximity it is reasonable to expect *P. lepturus* to be under similar influence of external factors (climatic variations and food availability) indicating that the Aride breeding population decline is not linked with external factors.

Additional work by Ramos et al. (2005) found that fledging success on Aride was significantly correlated with the El Niño Multivariate Index (i.e El Niño resulted in lower fledging success) but there was little evidence that productivity was influenced by local factors (hard tick infestations and intra and inter-specific competition) in general. Further to this, Catry et al (2009) determined that annual adult survival could not be linked to inter-annual variability in oceanographic conditions, but may be more influenced by *Pisonia grandis* fruiting events, which, overall, accounts for 23.2% of the adult mortality (*P.grandis* produces sticky seeds which trap and kill seabirds). Based on survival rates they predicted that the probability of extinction of this population would be 99% in 170 years and suggested some active management by maintaining some open areas both at canopy and ground level. *P. grandis* is native to Seychelles and thrives in acidic guano enriched soils. It is common across Aride, Cousin and Cousine, causing mortality across all seabird species that nest in its vicinity. Cousin for example has 69% *P. grandis* coverage (Hill et al. 2002), and despite *P. grandis* induced adult mortality of *P.lepturus* no decline in population has yet been recorded. One possible interpretation is that, although *P. grandis* is native to the archipelago, its fast post‐restoration establishment (Aride, Cousin and Cousine were all once coconut plantations) has led to possibly higher density than pre-plantation levels, because slower growing climax vegetation is yet to mature, though this doesn’t explain the differences observed between Aride and Cousin/Cousine. However, it may be due to internal management; with Cousine island actively raking *P.grandis* seeds during fruiting events and Cousin raking all pathways regularly. On Aride the pathways are also raked weekly but not actively targeting *P. grandis* like on Cousine. A 1170m2 costal path area was cleared between 2009 and 2011 and planted with native trees. The new vegetation management plan set up by the Island Conservation Society (Aride management) is planning to further clear 1.5 Ha of *P. grandis* in different areas to tackle the seabird entanglement issue (Calabrese 2017). If during the first year the areas are successfully cleared and maintained, the clearing effort can be increased in targeted areas for *P. lepturus*. Continuous monitoring of *P. lepturus* will continue in order to assess the beneficial effect of *P. grandis* removal on the breeding population. Raking *P. grandis* seeds in the monitoring area (5 Ha of plateau) should also be considered and included in the vegetation management plan. To conclude; we are not certain why the Aride breeding population is in decline but by pooling studies on *P.lepturus* between neighboring islands it has been possible to narrow down the possible causes. Further investigation is required into site specific internal factors influencing adult mortality.

***Monitoring Programmes***

We aimed to use the *P.lepturus* monitoring programmes to assess whether monitoring programme design was adequate to not only detect trends but to also distinguish the main influencing causes. For *P.lepturus* to truly be used as an indicator of ocean ecosystem health the site specific factors influencing fledging success and breeding population density must be distinguished from external factors. Whilst at Aldabra it was possible to rule out several predators as the potential cause of the decline in fledging success, it was not possible to distinguish further. Likewise for Aride, by comparing breeding population trends between islands we were able to assign the probable cause to be site specific. In order to build upon current knowledge and efforts and improve the value of data for *P.lepturus* throughout the Seychelles werecommend anationwide monitoring plan should be implemented with just consideration for the spectrum of resources available at each site. The following method recommendations are made:

1. A basic monitoring programme should consist of year-round monitoring of a designated area (with consideration for accessibility for regular monitoring and representative of typical nesting habitat) that is large enough to include a sample size of minimum 30 nests per year (30 is thought to be the minimum number in which all current programmes could continue based on nesting population size and accessibility of nest sites at these five sites). The designated area should then be monitored closely with sustained continuous effort to ensure all new nests are recorded and followed until breeding outcome is determined. This method allows for a multi-parameter monitoring programme, including data on overall fledging success but also seasonal and temporal fledging success and nest density to be recorded. The basic monitoring should record stage at failure.
2. Monitoring should be conducted a minimum of once every two weeks (though ideally more frequently) to ensure: a) that the number of new nests which fail in early stages are captured as much as possible and b) to endeavour to correctly record the stage at which nesting attempts failed.
3. Additional parameters may be included that do not enhance time or personnel required though add some complexity to the monitoring programme (and therefore must be explicitly described in a methods protocol). These may include: 1) a measure of nest site choice. Nest site is an important factor governing nest success, avoiding excessive cold and hot temperatures are essential for egg development stage as these can slow development and cause embryonic death (Grant 1982; Olson et al. 2006) and tropical seabird species have a more delayed onset of thermoregulatory capabilities when compared with those in temperate environments; therefore nest microhabitats and behavioural thermoregulation, are important factors during egg brooding and early chick development (Hart et al, 2017). Nest site choice can be recorded in terms of habitat type (e.g vegetation/rock crevice/tree limb etc) and site exposure (e.g level of shade, peripheral cover from weather, accessibility to predators etc). 2) Evidence or observation of predator interaction.
4. Any additional programmes that monitor the ecosystem that *P. lepturus* individuals interact with are beneficial and may be useful in determining or ruling out certain factors affecting nesting success. For example, monitoring trends in natural or invasive predators, vegetation phenology and climate variables.
5. Should a declining trend in fledging success be observed then further actions may be taken to determine cause, these may include the use of camera traps on nests to observe factors such as predation, chick feeding frequency and nest desertion by adult. If there is no obvious cause then further investigation of external factors such as climate, food availability may be investigated via satellite data coupled with geo-tagging birds.
6. To enable national level monitoring of *P. lepturus* a standardised protocol should be developed and followed at all sites coupled with a standard database format to ensure data management enables and leads to relatively frequent analysis which can provide site managers with the information to make appropriate and informed management responses.

*5. Conclusions*

The Western Indian Ocean has recently been identified as a key area to prioritize for the conservation of global marine biodiversity in the face of climate change (Ramírez et al. 2017). The Seychelles Archipelago supports the greatest abundance of seabirds in the tropical Indian

Ocean (Le Corre et al, 2012). Regional seabird population success and trend data is not readily available despite data being collected for many years at several locations. A greater effort must be made to streamline regional data and utilise the results to steer management practices and channel research resources towards the most critical areas. This study highlights a decline in nesting success at Aldabra atoll and a decline in nest abundance at Aride, both require further understanding and therefore management should focus research efforts and conservation resources at establishing likely causes of these declines. This is likely to be most successful by establishing holistic values across the region and managers working together to protect these values.

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|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Island** | **Protected Status** | **Total land area (ha)** | **Geomor-phology** | **Location** | **Max height asl (m)** | **General management** | **Population estimates** | **Nest predators** | **Other Disruptive\* species** |
| Aldabra Atoll | UNESCO World Heritage site (1982); Special Reserve (1975) | 15,254 | Coralline | 9.2255**°**S,  46.1310**°**E | 8 | Public Trust | 2000 pairs 1 | Black rat*,* grey heron, Aldabra drongo4  Coconut crab1 | Red-tailed tropicbirds |
| Aride | Special Reserve (1975) | 74 | Granitic | 4.2000**°**S, 55.6667**°**E | 134 | NGO | 1,446 pairs 2 | Seychelles skink, wright’s skink and Seychelles fody5 | *Pisonia grandis* (bird-catcher tree), big headed ants (until 2016), ticks. |
| Cousin | IUCN class 1A Special Reserve (1975) | 27 | Granitic | 4.3314**°**S, 55.6631**°**E | 69 | NGO | 2110 pairs 3 | Seychelles skink, wright’s skink and Seychelles fody, ghost crabs6 | *Pisonia grandis* |
| Cousine | Privately owned | 26 | Granitic | 4.3500**°**S, 55.6333**°**E | 72 | Private | 450–850 pairs8 | Seychelles skink, wright’s skink and Seychelles fody, ghost crabs 7, Seychelles magpie-robin. | *Pisonia grandis, giant tortoise,* big- headed ants. |
| Denis | Privately owned | 140 | Sand cay | 3.8000**°**S, 55.6667**°**E | <4 | Private | Unknown? | None perceived, cats removed in 2000, rats removed in 2002. |  |
| 1Diamond 1971, 2Burger and Lawrence 2000, 3Bowler et al. 2002, 4Recorded but unpublished, 5Observed but unpublished, 6Phillips 1987,  7Malan et al. 2010, 8Skerrett et al. 2001, \*Observed to or thought to hinder fledging success by increasing nest desertion or causing parent mortality. | | | | | | | | | |

Table 1: Details of the five islands in the study, including protection status, size, geomorphology, location, management/ownership, population estimates, nest predators and other potentially disruptive species.

Table 2. *P*.*lepturus* monitoring information for the five islands in the study.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Island** | **Area monitored (ha)** | **Dates of data collection** | **Frequency of monitoring** | **Methods** | **Nest Distribution** | **Nest Habitat Type** |
| Aldabra Atoll | ?? | Feb 2009– Nov 2016 | Continuous year-round monitoring, every 2 weeks | Survey of all nests in area | Only on lime stone islets or coastal outcrops. Only monitored on Picard the islets within the adjacent channel. | Lime stone cavities or cavities in dense vegetation on small islets and coastal outcrops. |
| Cousin Island | 20 | 2005–2007, 2009–2016 | Once/twice a year Feb and/or July | Survey of ca. 100 nests | Ubiquitous | Bare scratched patches inside rock or log cavities or against tree roots or boulders. |
| Aride Island | 5 | Jan 2011– Dec 2016 | Continuous year-round weekly monitoring |  | Ubiquitous though only monitored on coastal plateau. | Bare scratched patches inside rock or log cavities or against tree roots or boulders. |
| Cousine Island | ?? Becky | Jan 2007– Dec 2011 | Weekly | X fixed nest sites monitored | Ubiquitous though only monitored on accessible eastern side. | Bare scratched patches inside rock or log cavities or against tree roots or boulders. |
| Denis Island | ?? Jankse | Nov 2015–Sept 2016 | Weekly | X fixed nest sites monitored | Ubiquitous though more abundant in forest. Monitored island wide??? | Bare scratched patches inside rock or log cavities or against tree roots or boulders. |

Table 3. Number of *P. lepturus* nests monitored in study period, overall nesting success (% successful nests, i.e. fledglings) and the proportion of nests that failed at egg or chick stage at each site (%).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Island** | **Total nests monitored** | **# Mean annual nests monitored** | **# Mean annual nests successful (fledged)** | **# (%) of failed nests failed at egg/chick stage** | **Mean annual nesting success (± SE)**  **\* Mean monthly success** |
| Aldabra Atoll | 333 | 42 | 6.4 | 66 / 34 | 15.2% (± 2.29) |
| Aride | 1033 | 172 | 69 | 62/38 | 40.2% (± 3.8) |
| Cousin | 854 | 93 | 37 | 64/36 | 33% (± 4.04) |
| Cousine | 537 | 107 | 52.2 | 72/28 | 51.6% (± 2.9) |
| Denis | 39 | na | na | 61/39 | 55%\* (± 9.3) |

***Table 4:*** *Generalised additive model output for nesting density and fledging success. Trend refers to temporal change and season refers to changes observed on an annual cycle (seasonality).*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Model** | **Island** | **Term** | **e.d.f.** | **χ2** | ***p*** |
| success | Aldabra | trend | 1.00 | 7.61 | 0.006 |
| Aride | trend | 1.00 | 0.14 | 0.706 |
| Cousine | trend | 1.00 | 0.06 | 0.802 |
| nests | Aldabra | season | 0.64 | 1.17 | 0.151 |
| trend | 2.11 | 5.68 | 0.090 |
| Aride | season | 3.78 | 49.1 | 0.000 |
| trend | 1.60 | 35.2 | 0.000 |
| Cousine | season | 3.09 | 12.7 | 0.003 |
| trend | 1.99 | 9.25 | 0.014 |

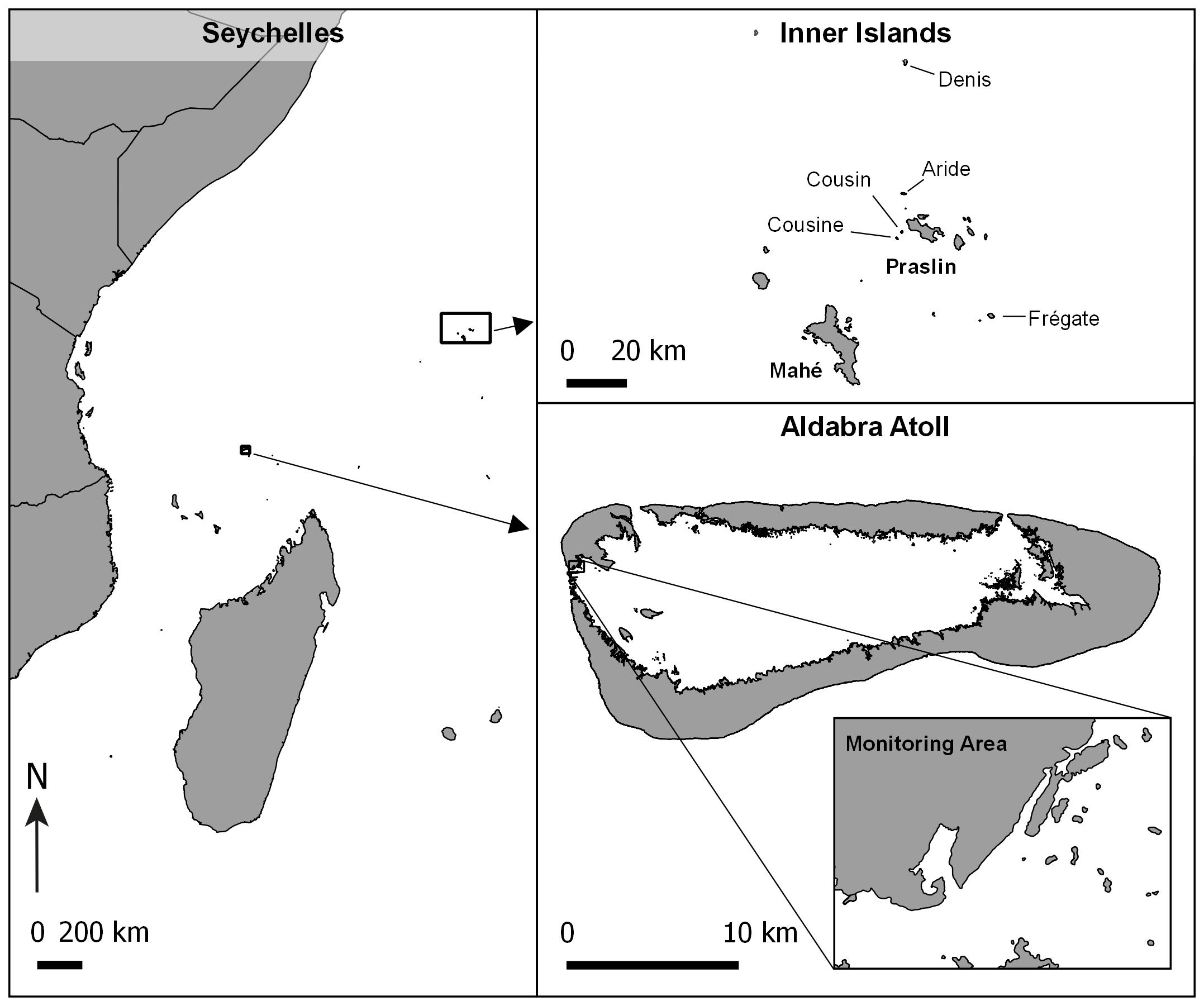


Figure 1: Map of Seychelles monitoring site locations

***trend-all-locations__20161114***

***Figure 2:*** *Long-term trends in (A) Nesting density of new P. lepturus and (B) probability of nesting success on five islands in Seychelles. Shaded areas indicate the corresponding standard error of the model predictions. Vertical bars indicate standard deviation for Denis island.*

seasonality-new-nest_20161114

***Figure 3:*** *Seasonality in nesting density of P. lepturus. Shaded areas indicate the standard error of the model predictions.*